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PLATE X

ABOVE:—The Royal Observatory, Greenwich, looking north towards the Thames, which is seen in the background at the left.

BELOW:—In the Astronomer Royal's garden. From left to right: E. W. Brown (Yale), F. Henroteau, Lady Dyson, Sir Frank Dyson, W. H. Greaves (Greenwich), C. R. Davidson (Greenwich), Daughter of Sir Frank and Lady Dyson.

Journal of the Royal Astronomical Society of Canada, 1927

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VOL. XXI, No. 8 OCTOBER, 1927 Whole No. 168

THE GREENWICH OBSERVATORY.

BY F. HENROTEAU

Approaching the coast of England from the Continent and beholding for the first time those imposing high white cliffs, Albion's girdle, one feels that behind that barren wall there can lie naught but wilderness. Shrouded and forbidding in the morning mist, nothing conveys to the mind of the visitor that warm hospitality and the beauty of centuries wait but an hour away to greet him.

He passes the ancient castle of Dover, resting like a mirage on the heights, and so lost is the traveller in the drift of past ages, that, almost with regret, he slips into the harbour, and finds himself again in the world to-day.

Stretching apparently without limit, there is London with its maze of traffic and people, an endless procession through its great stations, pouring forth and receiving ceaseless streams of life, and there the imposing Parliament Buildings reflect their gothic outlines in the waters of the Thames.

The visiting scientist, however, soon leaves all this turmoil, with its gripping human interest and confusion of tongues, to go in search of that Mecca of astronomers, Greenwich Observatory.

At the end of a pleasant journey the traveller comes to a quick turn, a sharp hill, a last run, and finds himself speeding along a magnificent avenue of ancient trees which leads to the Observatory, nearly hidden in clustering foliage.

There is a deep impression of home-coming as one approaches this venerable institution, founded in 1675 by royal edict of His Most Gracious Majesty, Charles II, and which had as its first director or Astronomer Royal, the Reverend John Flamsteed.

The accompanying photograph taken by the writer (Plate X) gives only a suggestion of the superb view from the top of the hill, particularly at sunset. Dimly in perspective one sees the Thames at

the foot of the slope, and beyond, the misty outlines of old London Town, its stateliness and terror, its tumult and its glory, by some magic still a part of the enchantment in this quiet place.

There is the centre of centres for innumerable scientists, it is the zero longitude, the origin of measurements in time as well as in position for most of the civilized world.

No more charming reception awaits the overseas astronomer than the hospitality offered by the present Astronomer Royal, Sir Frank Dyson. Through his courtesy one is free to wander about this famous place, which, for all its old traditions, lacks nothing of modern efficiency.

In the Octagon Room the visitor is temporarily transported to working methods of the seventeenth century, but when shown the special vaults which guard the delicate mechanisms of master clocks he begins to realize what is meant today by the word precision.

This odd Room is the nucleus of the observatory's growth. Originally it was the residence of Flamsteed; the upper floor was used for observing, the early observations being taken through the windows. Owing to the nature of the surroundings, all subsequent extensions have been to the south and east of the original building. By a sort of mathematical progression the dates of the instruments may be determined according to their distances from Flamsteed's house.

Eight successive Astronomers Royal have maintained the work of the observatory strictly along the lines originally laid down by royal command, advancing of course, with the march of science.

The falling of the time ball mounted above the central building still announces exact noon, and here especially in this naval observatory, from the testing and rating of marine chronometers and for other experiments, the conviction grows that astronomy has a vital relation to the amazing development of nautical science since the days when a sailor guided his craft by the north star.

Modern equipment includes the transit circle; the large alt-azimuth, the 28-inch equatorial, which, in the hands of Dr. Jackson, is now devoted to double star work; the 30-inch reflector employed in astrophysical research; the astrographic equatorial, which permits coöperation with many other observatories in producing the well known astrographic chart; and finally the photoheliographs, with which the sun is photographed every clear day.

After strolling through the observatory, another delightful hour awaits the visitor; there is tea with Sir Frank and Lady Dyson in the garden of their lovely old home, built in the days when Airy was Astronomer Royal, and the stranger within the gates comprehends the all-pervading atmosphere of comfort on Greenwich hill.

Enthusiast that he is, Sir Frank Dyson is particularly keen when touching on his chief interest, the stellar proper motions. This branch of astronomy he has pursued with vigour, and marked precision characterizes all his contributions.

Every astronomer knows of the sensational discovery, made by Kapteyn in 1904, that the stars in our relatively close astronomical neighborhood move in two intermingling streams. It was a first important step in our investigation of cosmical structure. A large share of the honour for this discovery is due to Bradley, who in the years 1750 to 1763, while he was Astronomer Royal, determined accurately the positions of 3240 stars brighter than the seventh magnitude.

Emulating the work of Bradley and Kapteyn, the study of stellar proper motions has been given a strong impetus by Sir Frank Dyson. An important part of the Observatory's resources and of the work of the staff, is directed to this subject. Besides several memoirs of his own, the Astronomer Royal is responsible for the compilation of important stellar catalogues. The value of these increases with time; they are the result of systematic observations, complete because they cover the entire field with which they deal, and perfect in the sense of being accurate as modern equipment and technique can make them. These catalogues practically form the solid foundation upon which astronomical progress is built, and must eventually lead to valuable discoveries.

Thus quietly and continuously information is accumulating which will some day answer the riddle of the star streams in sidereal immensity.

The Sphinx may hide its secret behind a faint enigmatical smile; Greenwich Observatory as confidently and as patiently prepares for that new scientific dawn when it may contribute to the revelation, rather than to the concealment, of a great mystery.

Dominion Observatory
1927 July 24th.

AGINCOURT AND MEANOOK MAGNETIC RESULTS FOR 1926

By W. E. W. Jackson

In the accompanying tables there is given a summary of the results of the observations made at the Canadian Magnetic Observatories at Agincourt and Meanook during the year 1926.

The values of Declination (D), Horizontal Force (H), and Vertical Force (Z), for Agincourt and of Declination for Meanook are obtained from the mean hourly values of the photographic records, based on absolute observations made once a week for Declination and Horizontal Force, and twice a week for Vertical Force. The mean monthly values of Dip (I), for Agincourt are derived from the means of H and Z. The mean values of H and I for Meanook are obtained from absolute observations made twice a month for H and once a week for I, and are uncorrected for diurnal variations, but are taken alternately morning and afternoon, so as to nearly eliminate this variation. The value of Z for Meanook is derived from the mean H and mean I.

All observations are corrected to International Magnetic Standard.

SUMMARY OF MAGNETIC RESULTS AT AGINCOURT FOR 1926

Lat. 43° 47′N.; Long. 79° 16′ W.

Agincourt Declination West

Month 1926	Mean of Month	Maximum	Date of Max.	Minimum	Date of Min.	Month Range	Mean Daily Range	
							From 24 hour readings	From Means of Extremes
	° ′	° ′		° ′		° ′	′	′
January	7 12.0	7 38.4	26	5 38.4	26	2 0.0	8.5	23.5
February	12.6	8 36.8	24	6 16.3	24	2 20.5	9.2	26.6
March	12.8	7 43.6	9	6 41.2	5	1 2.4	10.7	26.3
April	13.3	9 2.2	15	5 54.8	15	3 7.5	11.6	33.2
May	12.5	7 51.2	10	6 45.6	9	1 5.6	12.6	23.1
June	12.7	8 27.2	2	6 41.7	7	1 45.5	15.0	25.4
July	12.6	8 25.6	28	6 38.3	31	1 47.3	15.9	23.7
August	13.3	7 54.2	13	6 57.3	12	0 56.9	16.6	21.5
September	14.0	8 46.6	21	6 6.8	21	2 39.8	11.6	28.0
October	14.5	8 33.7	15	5 27.9	15	3 5.8	10.4	26.1
November	14.7	7 38.0	29	6 54.8	29	0 43.2	7.7	13.2
December	15.3	7 34.3	23	6 59.4	6	0 34.9	5.9	12.8

AGINCOURT HORIZONTAL FORCE

Month 1926	Mean of Month	Maximum	Date of Max.	Minimum	Date of Min.	Month Range	Mean Daily Range	
							From 24 hour readings	From Mean of Extremes
	γ	γ		γ		γ	γ	γ
January.....	15699	16029	22	15279	26	750	59.0	114.7
February....	15692	16073	23	15261	24	812	64.3	127.9
March.....	15691	15768	5	15394	5	374	55.2	117.2
April.....	15693	16099	14	15164	15	935	67.9	145.7
May.....	15699	15846	4	15340	10	506	59.2	120.9
June.....	15704	15988	1	15252	2	736	61.4	121.3
July.....	15706	15875	31	15355	28	520	52.3	99.7
August.....	15697	15752	9	15346	13	406	57.9	95.1
September...	15680	16056	15	15269	21	787	71.7	123.6
October.....	15677	16490	15	15420	15	1070	63.0	127.0
November...	15684	15722	11	15440	29	282	32.2	55.5
December...	15682	15723	3	15569	23	154	33.2	51.6

AGINCOURT VERTICAL FORCE

Month 1926	Mean of Month	Maximum	Date of Max.	Minimum	Date of Min.	Month Range	Mean Daily Range	
							From 24 hour readings	From Means of Extremes
	γ	γ		γ		γ	γ	γ
January.....	57583	58019	26	57456	18	563	26.9	46.3
February....	57579	57762	23	57394	24	368	20.3	47.2
March.....	57578	57676	9	57503	10	173	22.4	47.3
April.....	57558	57800	14	57087	15	713	32.6	72.0
May.....	57540	57662	4	57266	10	396	29.4	62.2
June.....	57524	57833	1	57247	2	586	23.8	63.1
July.....	57513	57607	31	57224	28	382	16.3	38.5
August.....	57504	57553	12	57303	13	250	12.3	36.5
September...	57497	57698	15	56989	21	709	37.2	74.7
October.....	57492	57650	14	57048	15	602	23.7	56.1
November...	57483	57515	28	57346	29	169	7.0	14.6
December....	57478	57496	23	57461	24	35	4.4	8.8

SUMMARY OF MAGNETIC RESULTS AT MEANOOK FOR 1926. LAT. 54° 37′ N.; LONG. 113° 20′ W.

MEANOOK DECLINATION EAST

Month	Mean of Month	Maximum	Date of Max.	Minimum	Date of Min.	Month Range	Mean Daily Range	
							From 24 hour readings	From Mean of Extremes
	° ′	° ′		° ′		° ′	′	′
January.....	27 9.0	29 24.3	26	25 41.5	18	3 42.8	7.2	45.0
February....	8.0	29 7.1	24	25 52.0	24	3 15.1	8.4	45.5
March.....	6.5	28 40.6	5	25 58.8	16	2 41.8	10.8	47.6
April.....	5.2	29 19.1	15	25 47.3	15	3 31.8	14.6	53.0
May.....	3.2	28 2.2	9	25 55.4	9	2 06.8	15.8	43.6
June.....	2.0	27 50.3	1	26 8.5	1	1 41.8	17.3	31.9
July.....	1.1	27 47.7	28	25 29.7	27	2 18.0	19.3	33.3
August.....	2.7	28 13.6	13	25 15.2	13	2 58.4	16.3	34.9
September...	3.8	28 58.0	21	25 33.2	21	3 24.8	11.6	45.9
October.....	4.0	28 57.9	15	25 9.9	4	3 48.0	8.6	47.9
November...	2.8	28 43.2	29	25 51.1	29	2 52.1	6.3	26.0
December...	2.0	27 50.3	23	25 41.1	23	2 9.2	4.4	23.1

MEAN MONTHLY VALUES OF *I* AT AGINCOURT AND MEANOOK AND OF *H* AND *Z* AT MEANOOK FOR 1926

Month 1926	Ag. *I*	Me. *I*	Me. *H*	Me. *Z*
	° ′	° ′	γ	γ
January	74 45.0	77 54.5	12830	59890
February	45.4	54.2	12838	59902
March	45.3	54.0	12829	59841
April	45.0	53.9	12841	59889
May	44.4	52.7	12851	59834
June	43.8	53.6	12839	59855
July	43.6	53.9	12847	59917
August	43.9	54.2	12823	59832
September	44.8	53.7	12823	59789
October	44.8	53.8	12817	59770
November	44.3	53.6	12829	59797
December	44.3	54.0	12822	59809

JUPITER

The year has wheeled, and lo, where lies unfurled
  The banner of the night king blown again
  To his effulgence, in lone power to reign
From couch of sun till dawn. A mighty world
Bedight with latent wonders,—graced and pearled,
  His noble retinue remoulds its chain
  Nightly to some new beauty; bands that stain
His radiant disc in changing shapes are whirled.
A globe of shadowy turmoil, vague unrest;
  Titanic swellings of the primal strife,
    Incessant throes of evolution, tending
    Perchance, through aeon after aeon wending,
  To some unparalleled abode of life,
Out of chaotic vapours slowly pressed.

Paris, Ont. GEOFFREY BELL.

SIXTY YEARS' PROGRESS IN ASTRONOMY

Adapted from an address given to Section III of the Royal Society of Canada at Ottawa on May 25th, 1927.

By J. S. Plaskett

As it is quite impossible to review the progress of any science for the past sixty years in the short time allotted, I must confine myself mainly to one aspect of astronomy and propose to contrast and compare present day ideas of the dimensions and form of the universe, one of the fundamental problems of astronomy, with those held at the time of the Confederation of Canada.

In 1867 astronomers had only a very limited idea of the dimensions and a vague notion of the form of the universe. Less than thirty years previously, in 1838, the first reliable measure of the distance of any star was obtained by Bessel, who found the parallax of 61 Cygni to be about a third of a second, corresponding to a distance of ten light-years, and by 1867 the parallaxes of less than a dozen stars were reliably known and no definite or adequate idea of the dimensions of the sidereal system was extant. The conception of the simple disc-like form of the universe, introduced by Wright a century earlier, was elaborated and confirmed by Sir William Herschel's early star gauging methods. Although the views of the latter were somewhat modified in the beginning of the 19th century, it cannot be said that there had been any particular progression in the prevailing ideas of the form of the universe by 1867. So far as the motions of the stars were concerned only a few hundred proper motions were roughly known at the time of Confederation, while the method of determining radial motions, another important factor in the problem, had not yet been developed. In the accompanying series of illustrations, especially drawn to give a graphic representation of the scale of the universe with linear dimensions increasing by a factor of 100, the certain knowledge of 1867 did not go beyond No. 7, the sun and the nearer stars.

It thus seemed almost a time of stagnation in the science. But this was only apparent as great developments, fated to change the

whole aspect of astronomy, were even then in progress. The centre of attention of astronomers was being diverted from the solar to the sidereal system, to accurate measures of the positions and motions of the stars. While progress may have seemed slow, this was due to the large numbers requiring observation, to the meticulous care required to obtain reliable values, and to the long intervals that must elapse between successive measures of position before reliable proper motions could be obtained. While we may have had to wait until the third decade of the twentieth century to reach, even provisionally, any generalization on the form and dimensions of the universe, we are now reaping the fruits of the advances initiated, the new methods of attack developed and of the preparatory work so carefully and accurately done in the past sixty years. The most striking result of these advances has been to extend outwards into space our conceptions of the dimensions of the universe as greatly as physics in the modern atomic theory has travelled in the opposite direction.

Probably the most important factor in this extension of the bounds of the universe has been the increase in the number and precision of the determinations of stellar parallax, and the development of new methods for obtaining the distances of celestial objects. The scant dozen stellar parallaxes of 1867 had barely reached a hundred, all visually determined, by 1900. The application of photographic methods and the coöperation of many observatories in this important problem has resulted in a rapid increase in numbers so that now the parallaxes of over 2,000 stars have been trigonometrically determined with a probable accuracy of one hundredth of a second of arc. But it is obvious that, valuable as it is for the nearer stars and important as forming the basis for less direct methods, the trigonometric method cannot usefully be applied to stars with a parallax approaching the hundredth of a second, or at a distance greater than two or three hundred light years from the sun. For more distant objects new methods of attack had to be developed and these methods with the results derived from their use, have constituted perhaps the most important advances in the aspect of astronomy under consideration.

The two most important additional methods of deriving stellar

distances, the statistical method and the luminosity method, both require in their use applications of stellar spectroscopy and before they can be intelligently discussed it seems necessary to interpolate a paragraph on the application of the spectroscope to astronomy. This has signalized probably the greatest advance in the history of the science, indeed marking the development of the sister science of astrophysics.

Spectroscopy was effectively only eight years old and was applied practically to the stars by Huggins only one year before the time of Confederation. That time may hence be said to mark the birth of astrophysics, which has given us a new and marvellous knowledge of the physical and chemical constitution of the heavenly bodies, as well as indicating, partially at any rate, the plan of evolution of the universe. One of the early applications was in the determination of the radial velocities of the stars, essential in the statistical method of obtaining stellar distances and in the discussion of stellar motions. Even more important perhaps have been the theoretical advances based primarily on experimental and observational spectroscopy and developed principally by the great school of English mathematical physicists. From the mere conjectures of sixty years ago, when any definite knowledge of the constitution of these forever inaccessible bodies was an undreamed of possibility, we now have a clear conception of the constitution, temperature, pressure and other physical properties of the external atmospheres of the stars. As a practical development of this advance, even though obtained empirically, the luminosity or absolute magnitudes of many of the stars can be obtained by the comparison of the relative intensities of certain lines in their spectra and hence, as will be seen later, their distance immediately follows. What seems even more incredible than knowledge of the external constitution of the stars, are the calculations now available of the conditions in the interior where the temperatures rise to millions of degrees,—forty million at the centre of the sun. The stable radiating mechanism we call a star is an example of the remarkable balance of forces in the interior, the force of gravity acting inwardly being opposed by the gas pressure due to temperature and by the radiation pressure against

the opacity, acting outwardly. The calculation of the conditions necessary for such a balance, beautifully developed by Eddington, have resulted in the very important relation, amply confirmed observationally, that the total brightness, "absolute magnitude", of a star is practically independent of its external temperature and is a simple function of its mass. The application of this relation to the determination of luminosity and hence of distance, when the mass is known, is obvious. While our knowledge of the constitution of the clusters and nebulæ is not so definite as in the case of the stars, great progress has been made and there can now be presented a picture, imperfect and incomplete though it may be, of the constitution and evolution of the universe, thus supplementing that of its form and dimensions now being considered.

The statistical and luminosity methods of obtaining stellar distances, after this necessary digression, can be now effectively described. Although the statistical method cannot be applied to individual stars, the average distance of a group of stars, its mean parallax, at distances beyond the range of the trigonometric method, can be reliably determined. Accurate values of the proper motions and radial velocities of the stars are required and it is of interest to note that in the sixty years the number of reliable proper motions has increased from some 300 to over 10,000 and of radial velocities from 0 to over 3,000. As is well known and determined from the radial velocities, the sun is moving through space towards Lyra with a velocity of about 20 km. per second. In consequence, the stars appear to move in general in the opposite direction. This parallactic motion, as it is called, being the component of the proper motion in that direction, will obviously be greater the nearer the stars, and from it, with the known velocity of the sun, the average distance of a group of stars can be easily calculated. Other methods of a similar nature, using both the proper motions and the radial velocities, give also the mean parallax of groups of stars and these statistical methods have been widely applied in studies of stellar distribution and other investigations.

The luminosity method of obtaining stellar distances has, however, been by far the most fruitful in extending the known bounds of the universe. While the trigonometric method is limited to

distances of two or three hundred, and the statistical to distances of a few thousand, the luminosity method has been successfully applied to celestial objects at distances of about a million light years. It is based on an application of the well known law of the decrease of brightness as the inverse square of the distance. It is known from careful measures that the sun would shine as a star of about the fifth magnitude if removed to a distance of 33 light years, corresponding to a parallax of one tenth of a second. If the apparent magnitude of any star is known, and this is a readily measurable quantity, and its luminosity or relative brightness compared to the sun can be determined, it is evident that its distance can be easily calculated. A fruitful method of obtaining the luminosities of stars from their spectra, which has already been applied to over 2,000 stars, and a second method, from the relation between luminosity and mass, have been referred to in the paragraph on spectroscopy. The most important method of deriving the luminosity of stars, however, is the relation between the period and the luminosity of Cepheid variables, first noted by Miss Leavitt and later developed and extended by Shapley. As will be seen later, our knowledge of the clusters and nebulæ and of the dimensions of the universe depends upon the use of this relation in deriving stellar distances.

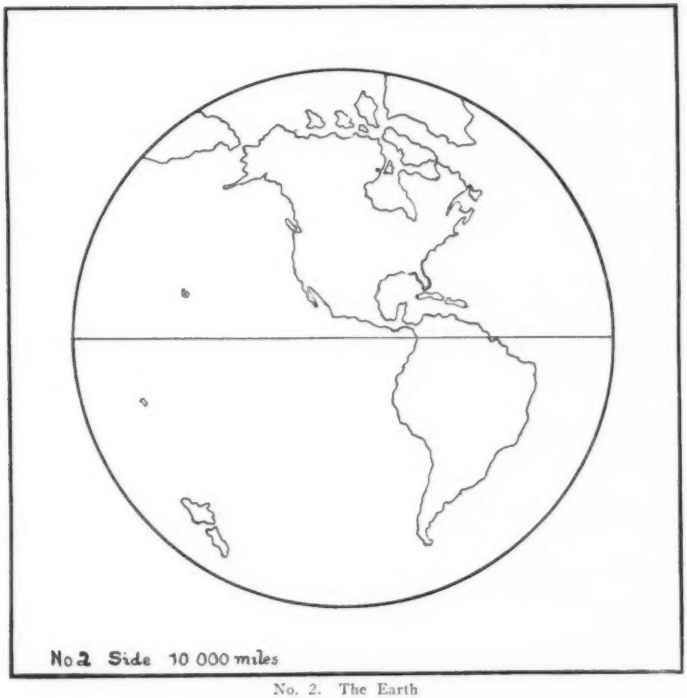
With this brief description of the methods used for gauging the dimensions, we are now in a position to review the progression in our conceptions of the dimensions of the universe for the last sixty years and the present state of knowledge on the subject. In 1867 and for two or three decades later, little was known, outside the general conception of the disc-shaped form and complex structure of the sidereal system, as to its dimensions and extent. It was not until the twentieth century that increasing knowledge of the distances and motions of the stars made estimates of the dimensions possible. In 1905 Newcomb and Seeliger estimated the diameter of the watch-shaped sidereal system as about 7,000 light years, a similar estimate being reached Hertzsprung a year later. This was extended by Walkey in 1914 from added data to some 10,000 light years and was further extended from considerations of a general nature by Eddington to perhaps 15,000 light years. The most general and complete investigation of the dimensions and structure

	SCALE OF UNIVERSE.		
-9	. 000 000 000 000 06 in.	1.6×10^{-13} cm.	Electron.
-8	.000 000 000 006 in.	1.6×10^{-11}	
-7	.000 000 000 6 in.	1.6×10^{-9}	
-6	.000 000 06 in.	1.6×10^{-7}	Atom.
-5	.000 006 in.	1.6×10^{-5}	Soap Bubble.
-4	.000 6 in.	1.6×10^{-3}	Tissue Paper.
-3	.06 in.	1.6×10^{-1}	
-2	6.3 in.	1.6×10	
-1	.01 m.	1.6×10^{3}	
0	1 mile	1.6×10^{5}	
1	100 m.	1.6×10^{7}	
2	10 000 m.	1.6×10^{9}	Earth.
3	1 000 000 m.	1.6×10^{11}	Earth Moon.
4	100 000 000 m.	1.6×10^{13}	Earth Sun.
5	10 000 000 000 m.	1.6×10^{15}	Solar System.
6	1 000 000 000 000 m.	1.6×10^{17}	
7	17 light years	1.6×10^{19}	Nearer Stars.
8	1700 l.y.	1.6×10^{21}	Local Cluster.
9	170 000 l.y.	1.6×10^{23}	Galaxy.
10	17 000 000 l.y.	1.6×10^{25}	Nearer Spirals.
11	1 700 000 000 l.y.	1.6×10^{27}	6 times Range 100 in.
12	170 000 000 000 l.y.	1.6×10^{29} cm.	Einstein Universe.

No. 1. Table of Dimensions of the Universe.

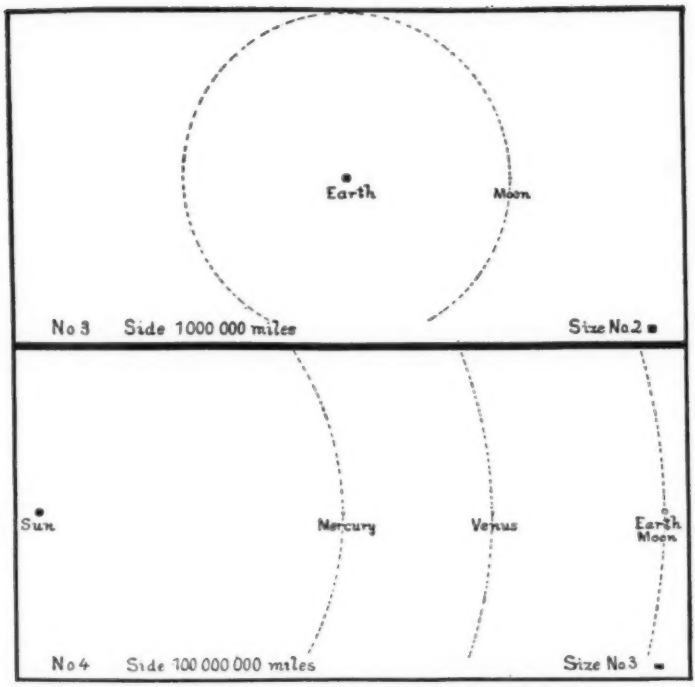
of the sidereal system is, however, due to Kapteyn, who, from investigations of the distribution, distances, motions and brightnesses of the stars, covering practically his whole lifetime, finally reached a provisional conclusion about 1920 as to the density distribution of the stars in space. The gradual thinning out of the stars with increase of distance from the sun proceeds in a fairly regular manner, the diameter corresponding to a density of one tenth that of the solar neighbourhood being about 18,000 light years with a thickness about 3,500. For a density one hundredth of that near the sun, which may perhaps be considered as the limit of the system, the diameter was found to be about 55,000 with a thickness about 11,000 light years.

It must not be forgotten, however, that all the above investiga-



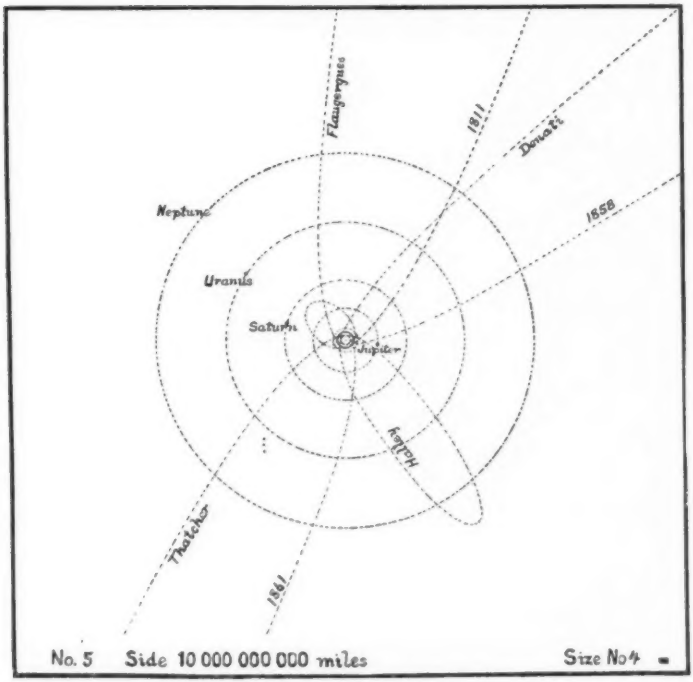
No. 2. The Earth

tions refer to a simplified or ideal form of the stellar system, and attack the problem indirectly through a determination of the density, luminosity and velocity functions from limited observations of the brighter stars only. They take no account of the obviously complex star clouds and clustering in the Milky Way, of whose distances practically nothing is known, and are admittedly incomplete and uncertain. However, a new method of attacking the problem and a further stride in the progression of increasing distances was given by Shapley at Mt. Wilson about 1918 who, from determinations of the distances of the globular clusters, assigned to the Galactic System a probable diameter of 300,000 and a thickness of 12,000 light years. Shapley's work was epoch-making on account of the enormously greater depths of space reached and because of the application of



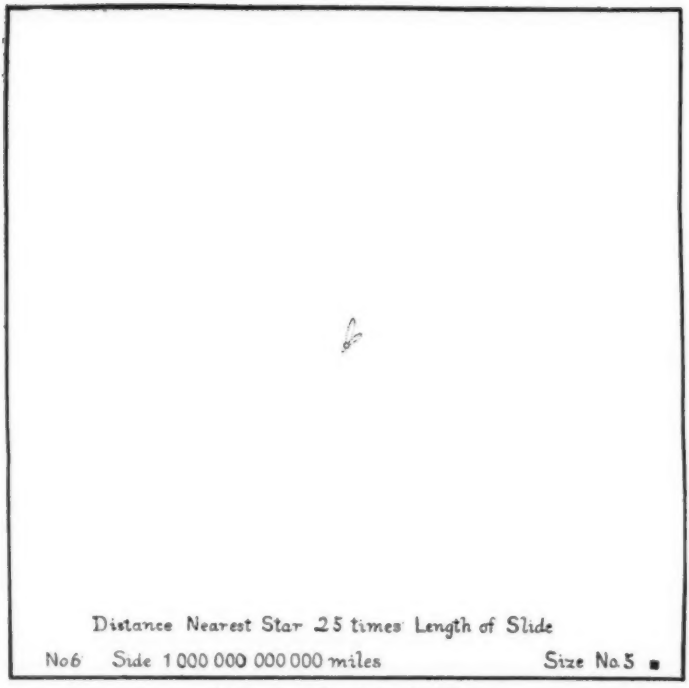
No. 3 and 4. The Earth-Moon and Sun-Earth Systems

the luminosity method to this purpose. Miss Leavitt had earlier shown, from the study of variable stars in the Magellanic Clouds, that increase of period in the Cepheid variables was accompanied by increased brightness in a definite way, and Hertzsprung applied this to derive the distance of the Lesser Cloud. Shapley, however, by an elaborate investigation of the Galactic Cepheids and by correlation of the latter with Cepheids in the clusters and Magellanic Clouds, accurately determined the form and zero point of this important relation, generally called the Luminosity Period Law, and applied it to obtain the distances of the globular clusters. In a masterly and laborious investigation he determined the distances of the 86 known globular clusters and found them to range between 20,000 and 200,000 light years from the sun. Plotting their distribu-



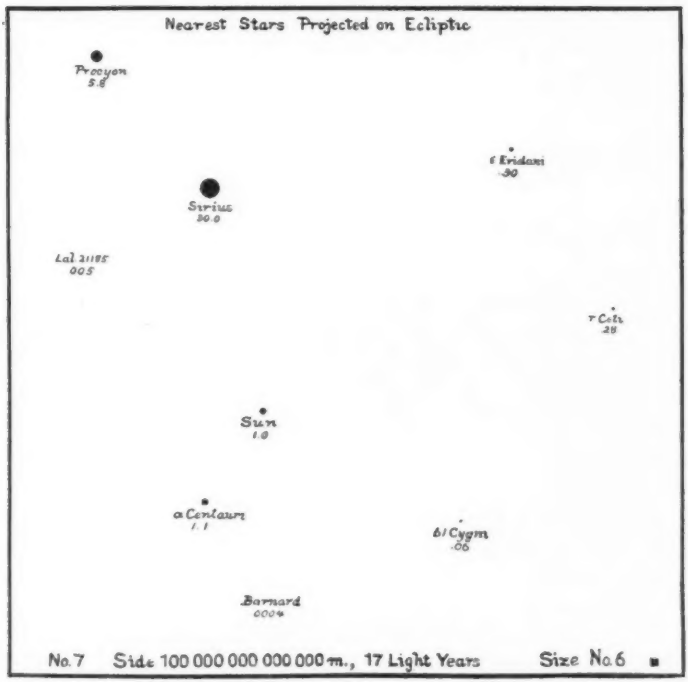
No. 5. The Solar System

tion with respect to the Galaxy, he found they were symmetrically distributed, 43 on each side, in a roughly ellipsoidal form about the galactic plane as seen in No. 9 of the illustrations. Although their motion is generally towards the Galaxy, he found that none of the globular clusters were nearer than 5,000 light years to the central plane, in contrast to the open clusters, almost exclusively within the system. This led him to the theory that the dynamical forces encountered when a globular cluster penetrated the Galaxy were sufficient to destroy its equilibrium and dissipate it into an open cluster, and to the assumption that the Galactic System, composed as it is of star clouds and open clusters, may have been partly constituted in this way. From the symmetry of the globular clusters to the Galaxy and the presence of open clusters within it, Shapley



No. 6. The Emptiness of Space.

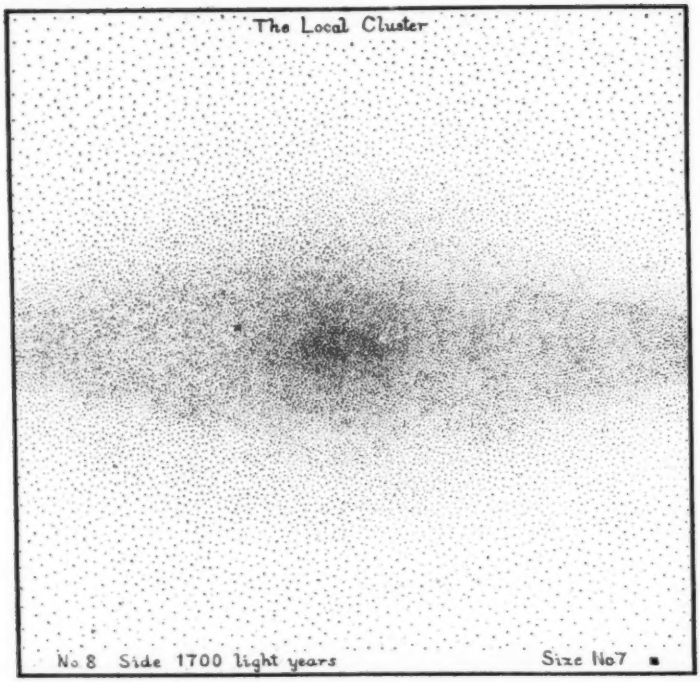
reasonably concluded they must be dependent members of the Galactic System, which must hence be co-terminous with the Globular Clusters, some 300,000 light years in diameter and 12,000 thick. He found that the sun is situated somewhat eccentrically within a watch-shaped star cloud about 5,000 light years in diameter and that this cloud, generally called the "local cluster," is inclined about 12 degrees to the galactic plane. A probable representation of the local cluster is shown in No. 8 of the illustrations with the position of the sun represented by a cross. The scale of this figure could not include the whole of the cluster which extends longitudinally considerably beyond the sides. This "local cluster" is quite eccentrically situated, however, as the centre of the whole Galactic System is about 60,000 light years from the sun in the direction of Sagittarius where, as is



No. 7. Our Nearest Neighbours in Space in Their Relative Brightness.

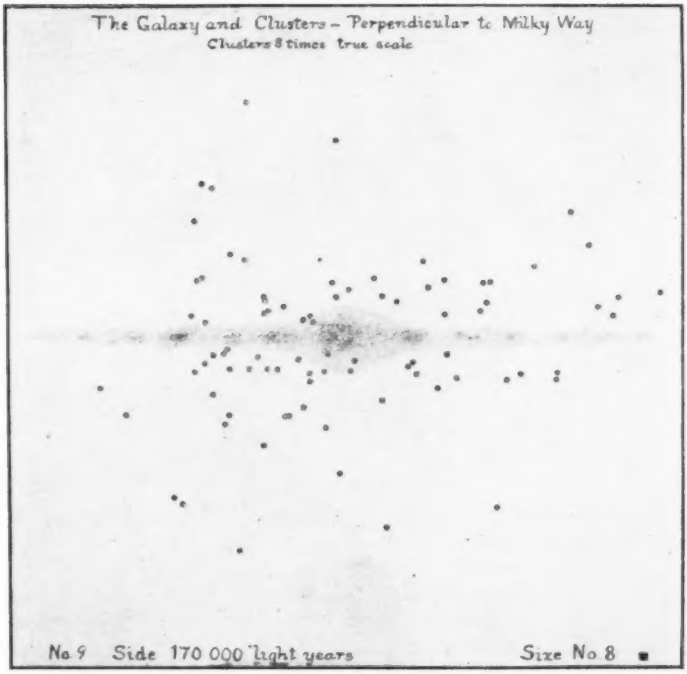
known, the star clouds appear exceptionally dense. This eccentric location of the sun should effectively shatter any belief in its importance or its central position in the Cosmos.

This is truly a magnificent and impressive picture of the Galactic System, containing several thousand million stars, and including within its confines not only the great star clouds of the Milky Way and the planetary and diffuse nebulæ but the open and globular clusters. While more recent work has tended to reduce Shapley's cluster distances and hence the scale of the Galaxy by some thirty per cent, the question is not yet finally settled, and it can be safely said that his general conclusions have not been seriously contested. While it is conceded that we have no direct evidence of galactic stars at a greater distance than 20,000 light years, that is probably



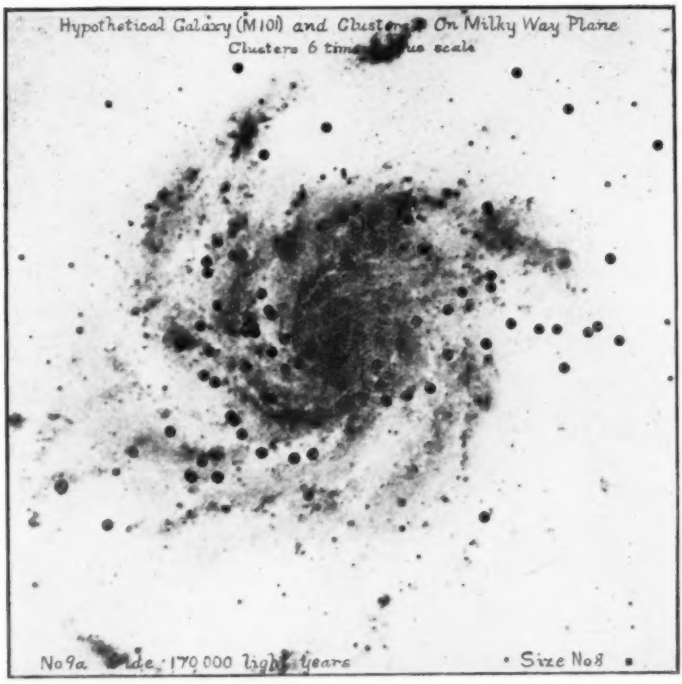
No. 8. The Local Cluster.

because no concerted search has yet been undertaken for such distant objects. It will be of interest to refer to the accompanying illustrations depicting the scale of the universe. No. 9 and No. 9*a*, in which the position of the sun is represented by a cross, must not be taken too seriously as they represent a purely imaginative conception of the form of the Galactic System. Nevertheless, this conception is not improbable from analogy with the nearer spirals, the base of 9*a* being a photograph of M101, which, as will be seen below, are now considered as outside galaxies of a similar constitution and order of dimensions. The scale attached was reached, obviously, from the starting point of 1 mile and must be taken as approximate only as the diameter is probably greater than 200,000 light years.



No. 9. Relation of the Globular Clusters to Galaxy; Perpendicular to Plane.

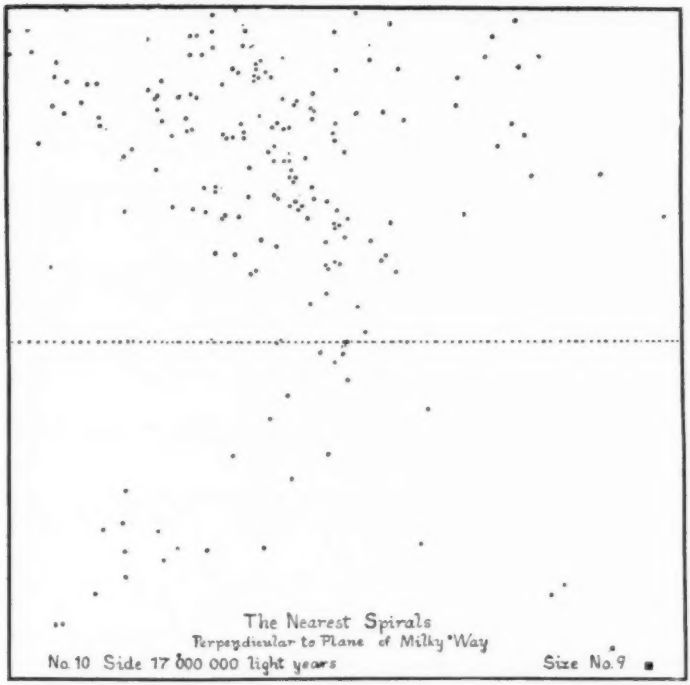
Shapley's conception of the Galaxy included the clusters and the diffuse and planetary nebulæ but avoided definite consideration of the place of the spiral and other extra-galactic nebulæ, probably because no reliable information as to their distance was then available, although he tentatively considered them as subsidiary to the Galaxy. The place and position of the spirals in the Cosmos has been hotly debated for many years and has been the subject of two opposing schools of thought. The earlier school, which prevailed generally until some ten years ago and has had strong advocates throughout, considered the spirals as outside galaxies or "Island Universes", with distances of the nearer ones of the order of a million light years. The other school, based on the measures of



No. 9a. Relation of the Globular Clusters to Galaxy; Projected on Plane.

proper motions in some of the spirals by van Maanen and the theoretical work of Jeans, estimated the distance as of the order of 10,000 light years, hence making them subsidiary to our Galactic System. This view commanded fairly general acceptance for a few years, but the pendulum of opinion has again swung back, in the last year or two, to the Island Universe theory.

This last stage and the most recent extension of our views of the dimensions of the universe is due to Hubble of the Mt. Wilson Observatory, who has recently discovered several Cepheid variables in some of the brighter spirals and has carefully determined their periods. The application of the Luminosity Period law derived by Shapley has enabled the distances of these objects to be reliably



No. 10. Distribution of the Nearer Spirals; Perpendicular to Galactic Plane.

determined. As the same luminosity standards were used as by Shapley, there seems no question, however conflicting the views on the correction to Shapley's scale, that the relative values of the size of the Galaxy and the distances of the clusters and nebulæ are substantially correct. Thus Hubble was able to show that the Andromeda Nebula had a diameter of 45,000 and was at a distance of 900,000 light years and that the corresponding figures for the spiral in Triangulum were 16,000 and 870,000 light years, thus indicating systems which, though not so large, are of the same order as Shapley's dimensions of the Galaxy and justify by their size and importance the designation of "Island Universe."

Hubble, by means of assumptions of a fairly probable character as to comparability of diameter and brightness of the spirals, was

able to deduce that the average separation of the spiral and other extra-galactic nebulæ from one another was of the order of 1,700,000 light years and that the average mass was equivalent to 260,000,000 suns. The average density of space corresponding to these dimensions is 1.5×10^{-31} grams per cubic centimetre, equivalent to 1 lb. of matter diffused uniformly over a cube of space with sides 1,000,000 miles long. This exceedingly small average density, however, is several million times less than Eddington's recent value for the diffuse matter in the Galaxy. From this density, Hubble, by applying Einstein's equations for a spherically curved space, obtains as the radius of this particular hypothetical space 85,000,000,000 light years. He estimates this distance as about 600 times the possible range of the 100-inch telescope, thus leaving an ample margin of unexplored and apparently unexplorable space for the imagination. While the tendency of the past sixty years, as we have seen, has been vastly to extend our conceptions of the size of the universe, it seems reasonably certain that a proportionate increase can hardly be expected in the future. The distribution of the nearer spirals, showing their peculiar arrangement with respect to the Galaxy and their complete avoidance of the galactic plane, the latter being represented on proportionate scale, is shown in No. 10 of the illustrations which is plotted from data obtained from Hubble's tables. The tremendous extent of the spherical relativity universe can be better imagined when it is realized that two additional figures on the same hundred-fold ratio would be required to reach the boundary.

It should be of interest to Canadians to learn, in concluding this review of the progress made in our conceptions of the universe since Confederation, that Canada's contribution to modern astronomical research is one of which every Canadian has good reason to be proud, as to the best of my knowledge, it is unequalled relatively, so far as Government support is concerned, by any other country. Canada with its small population and its relatively short span of national life has established and supports two national observatories of the first rank, one of these having the second largest telescope in existence, and both making important contributions to science.

Dominion Astrophysical Observatory
Victoria, B.C.

MEETING OF THE AMERICAN ASTRONOMICAL SOCIETY

By C. A. Chant

The thirty-eighth meeting of the American Astronomical Society was held at the University of Wisconsin, Madison, on September 6, 7 and 8, 1927. About 75 members and guests were in attendance, largely from the middle west, though the eastern observatories were fairly well represented.

The City of Madison has a population of about 50,000 and is beautifully located on the shores of two small lakes. The surrounding country is very similar to that part of Ontario tributary to Toronto. It is pleasantly diversified by lakes, valleys and hills which are decorated with oak, elm, willow, maple and other familiar trees. Considerable tobacco also is grown. The farms are well kept and the cattle numerous. The farm buildings are good and present a neat appearance in their white, yellow and red-brown paint. High-tension electric transmission lines are also to be seen, though they are not so prominent as in Ontario, the home of publicly-owned utilities.

Madison is the capital of the state and therefore the seat of government. Its legislative buildings are on a commanding site and present a creditable appearance. The University also has a charming location on the south shore of Lake Mendota. It is a great modern seat of learning, is well known for its researches, and is famous for the manner in which it has contributed to the solution of the special problems met in the agriculture and industry of the state.

The Washburn Observatory was established in 1878 through the beneficence of Governor C. C. Washburn. Its chief instrument is a 15½-inch refractor by Alvan Clark & Sons. At present by means of it stellar photo-electric measurements are being carried out. The student's observatory possesses a 6-inch telescope, the objective of which is the very one used by Burnham in his epoch-making double-star observations. The original wooden tube of the telescope is still

preserved at the observatory and was examined with interest by the visitors.

The present director of the observatory is Professor Joel Stebbins who succeeded Professor G. C. Comstock on his retirement a few years ago. Professor Comstock is president of the American Astronomical Society and Professor Stebbins had been its secretary for a number of years but retired at the present meeting. Thus the society met at the home of both its president and its secretary, an unusual coincidence.

Three fraternity houses situated on the shore of the lake, were very courteously placed at the service of the society and thus the members were brought into continuous intimate association.

Some twenty new members were elected and Professor R. S. Dugan, of Princeton, was chosen new secretary.

On Tuesday evening, September 6, Professor and Mrs. Stebbins received the members at their home on Observatory Hill and a very pleasant time was spent in greeting old friends and making new ones. On Wednesday afternoon there was a delightful drive around the lake (30 miles) and a reception at Professor Comstock's summer residence on the north side of the lake. Then on Thursday evening, after the papers had all been presented, there was a special dinner. A number of addresses were given, and the present writer will be pardoned if he specially mentions two of them, namely, Professor Dugan's relation of the experiences of an expert witness and Professor Philip Fox's story of a foreigner's experience as a commuter.

Following is a list of papers on the Programme:—

1. O. L. Dustheimer: Spectroscopic observations of Phi Persei.
2. Nicholas T. Bobrovnikoff: On the spectra of comets.
3. Hazel Marie Losh: The velocity curves and period of Zeta Tauri.
4. W. W. Morgan: Spectrographic and photometric observations of C P Cygni.
5. R. E. Wilson: On the K-term in radial velocities.
6. E. W. Brown: Gravitational effects in spiral nebulae.
7. Joel Stebbins and T. S. Jacobsen: Tests of the solar variation by photometric measures of Uranus.
8. Dean B. McLaughlin: Masses and luminosities of the eclipsing binaries.

9. J. J. Nassau and P. D. Wilkins: Graphical determination of orbits of visual binary stars.
10. G. Van Biesbroeck: Definitive orbit of Comet Delavan 1914 V.
11. Elliott Smith: Meridian circle observations of Eros comparison stars.
12. Issei Yamamoto: A remarkable meteor connected with the Winnecke Comet, photographed at Mukden.
13. E. A. Fath: A proposed English translation of Copernicus' "De Revolutionibus."
14. L. J. Comrie: Occultation of a seventh magnitude star by Jupiter on Dec. 7, 1927.
15. E. C. Phillips: Personal equation in observing occulations (preliminary report).
16. H. W. Geromanos: New demonstration equipment for astronomy teachers.
17. H. T. Stetson and L. B. Andrews: A modified form of the projection method for the measurement of solar photographs.
18. Donald H. Menzel: The spectra of Jupiter and Saturn.
19. G. Van Biesbroeck: A test of cometary refraction by means of Comet Pons-Winnecke.
20. B. Boss: On the variable rotation of the earth.
21. E. B. Frost: The Barnard atlas of selected regions of the Milky Way.
22. Philip Fox and Miss Bennot: Parallaxes from Dearborn Observatory.
23. C. M. Huffer: Photometric observations of red stars.
24. O. Struve: Spectrum of Nova Aquilæ 1927.
25. F. Slocum: The Van Vleck Observatory eclipse expedition.
26. W. S. Adams: Mt. Wilson stellar spectra with high dispersion.
27. F. E. Ross: Photographs of Venus.

THE PLANET JUPITER

A Concise Tabulation of Many Items of Interest to the Amateur.

By W. G. Colgrove

Name—The Egyptians gave this planet the name of their greatest god, Hôr. who was the hawk-headed double crowned god of the sun. The Chinese named it The Regulator because of its regularity of motion. The Greek name was Zeus, the father of all the gods and ruler of Mt. Olympus. The Romans called it Jove, or Jupiter, of the crashing thunderbolts.

Myth—According to the Greeks, Zeus was one of the sons of Chronos and Ops, while the Romans called him Jupiter the son of Saturn and Rhea, but these parents are not properly identical. As Saturn had driven Ophion from the throne of Olympus, so Jupiter, in turn, drove Saturn from his high position and became the father and ruler of a younger generation of deities. The imperious Juno, attended by the rainbow and the peacock, was his beautiful queen.

Symbol—The sign of Jupiter is ♃ and is supposed to represent a flash of lightning, or Z, the first letter of Zeus.

Sound—In the Music of the Spheres, Jupiter was assigned the part of bass, not however, so deep as Saturn.

Colour—To unaided vision Jupiter is a yellowish white, but in a large telescope, under good seeing conditions, there appear a variety of tints—pink, amber and brown.

Markings—There is a broad, light-coloured equatorial band or belt about 10,000 miles wide, while above and below it are two darker belts of almost equal width. These are followed, toward the poles, by other narrower belts that present a rippled appearance. This banded effect pertains only to the cloud envelope which is so dense and deep that the actual surface of Jupiter is not visible. On account of the rapidity of rotation these markings are always changing. Sometimes, because of great cyclonic storms, large coloured spots appear for a time, as in 1878, when a great oval pink spot 30,000 miles long and 7,000 miles wide appeared; but these spots must not

be confused with sun spots which are utterly different in origin, nature, matter and form.

STELLAR MAGNITUDE—From -1.5 to -2.5 the brightest of all the planets except Venus and about five times as bright as Sirius, the brightest star.

ANGULAR DIAMETER—This varies from 32″ to 50″ of arc according to distance from us. Recently it has been set at 35.44″ of arc for the polar, and 37.72″ of arc for the equatorial diameter, a flattening of 1/18.

LINEAR DIAMETER—Polar 84,000, mean 86,700, equatorial 88,000 miles This makes it the largest of all the planets, somewhat more than 10 times the earth's diameter and slightly more than 1/10 of the sun's. The circumference will be about 270,000 miles.

AREA OF SURFACE—About 23,232,000,000 square miles, or 118 times our earth. The surface, however, is probably still in a semi-gaseous state.

VOLUME—Slightly more than 1,300 times the size of our planet.

MASS—318 times our earth and about .001 of the sun. Nearly three times as great as all the other planets together.

DENSITY—.242 of our earth, or 1.32 of water, or about the same as the sun. This would indicate a gaseous condition.

GRAVITY—2.65 times our earth. Falling bodies would attain in one second, a speed of some 40 ft. per sec. as compared with 16 ft. per sec. here.

ROTATION—Mean 9 hrs. 55 min. similar to Saturn. But this period, we must remember, is for the cloud-envelope only. The equatorial belt rotates a little faster, in about 9 hrs. 50 min., so that in 85 rotations the equator gains a whole rotation on the upper and lower portions. Jupiter has about 10,400 days in his year.

EQUATORIAL VELOCITY—7.73 miles per sec., 464 miles per min., 27,800 miles per hr., about 26 times faster than our earth. This high speed causes the polar flattening which amounts to .56 and also the equatorial bulge, and it may produce heat to supply the loss of solar radiation on account of distance. It also gradually reduces the superficial gravity from the poles to the equator by about 1/12 at the latter point. This will also be responsible for the violent equatorial winds that rage at 250 miles per hour, causing most of the surface changes we observe.

Distance from Sun—460, 483, 507 millions of miles, being the perihelion, mean and aphelion distances. Jupiter is more than 5 times as far from the sun as we are, and it would take a string of 5,600 of these gigantic spheres to reach between it and the sun.

Distance from Earth—369, 483, 576, millions of miles, being the distances at opposition, mean and conjunction.

Diameter of Orbit—About 960,000,000 miles, the circumference being in the neighborhood of 3,020,000,000 miles.

Revolution (*Sidereal Period*)—11.86 of our years, or 11 yrs. 10 months 17 days. The mean daily eastward motion is about 5′ or 299″ of arc, and it takes some 4332 of our days to make the annual round trip.

Revolution (*Synodic Period*)—Mean 399 days, or 1 year, 1 month, 3 days. This is the average interval between oppositions or conjunctions as seen from the earth.

Velocity in Orbit—8 miles a sec., 29,000 miles an hour, 712,000 miles a day. Like Saturn, its orbital and equatorial velocities are almost the same.

Arc of Retrograde—9 degrees. There are 121 days of retrograde and 279 days of direct motion each year.

Eccentricity of Orbit—.048. This changes the planet's distance from the sun by about 47 millions of miles. This is so small that there is no appreciable difference in the intensity of the sun's light and heat, and it causes but slight change in the planet's speed.

Light and Heat—.037 of the amount we receive—that is, we get about 27 times as much, but, as we have remarked, Jupiter may be partially self-luminous, and yet it sends to us only about .001 of the amount we get from our moon.

Albedo—Mean .56 though sometimes it is as high as .7, the same as Venus at times, but still only second to that brilliant planet.

Temperature—So far as solar radiation is concerned the surface of Jupiter would be frigid at about 200 degrees below zero. But it is certain that the temperature is not really so low, and that powerful internal sources produce the temperatures which have been measured.

Atmosphere—In the spectrum of Jupiter there appear certain dark bands which indicate a very dense atmosphere, but the exact

nature of it is in doubt because there is no other spectrum just like it. The clouds which apparently cover the entire surface must be composed of some substance other than water-vapor or they would have been frozen long ago.

Inclination of Axis to Orbit—86 degrees 55 minutes. This is the angle between the direction of the axis and the plane of the orbit, and in this case is so small that the axis is almost perpendicular to the orbit. Naturally this will result in almost perpetual seasons with almost no climatic changes.

Inclination of Equator to Orbit—3 degrees, 5 minutes. This is the angle between the plane of the equator and the plane of the orbit. It is small and the more than 10,000 Jovian days will each be about the same length throughout the long year.

Inclination of Orbit to Ecliptic—1 degree, 18 minutes, 41 seconds. This is the angle between the plane of the orbit and the plane of the ecliptic, and is also very small. These inclinations together with the high speed of rotation and the four fine moons being eclipsed every few days. make a most remarkable object for observation.

Pole Star—Because of these very slight inclinations the pole star of Jupiter cannot be far from the pole of the ecliptic, and is found in the heart of Draco.

Phases—These are very slight and are always gibbous at or near quadrature on the limb farthest from the sun. Otherwise it is always full.

Conjunction—These occur every 399 days, or more than 11 times in a Jovian year, but about five weeks later each time.

Elongation—This is the angle between a planet and the sun and may be either east or west. When it is 0 degrees the planet is in conjunction, when it is 90 degrees, it is in quadrature, and when it is 180 degrees it is in opposition.

Quadrature—The inner planets do not attain this position, but the outer ones attain it twice each year—east and west of the sun. There are 175 days between east and west quadratures.

Opposition—These occur on the opposite side of the orbit from the conjunctions and like them every 399 days, during retrograde

motion, and five weeks later each time. This is the best time for observation.

SATELLITES—These are 9 in number. The first four are the largest, were discovered in 1610 by Galileo and have been called the Galilean satellites and the Medicean stars. No. 1 (Io) is of magnitude 6.5, diameter 2450 miles, distance from Jupiter 261,000 miles, revolves in 1 day, 18 hours, 28 minutes. No. II (Europa) is of mag. 6.5, diameter 2050 miles, distance 415,000 miles, revolves in 3 days, 13 hours, 14 minutes. No. III (Ganymede) is of mag. 6, diameter 3560 miles, distance 664,000 miles, revolves in 7 days, 4 hours; No. IV (Callisto) is of mag. 7, diameter 3350 miles, distance 1,167,000 miles and revolves in 16 days, 16 hours, 32 minutes. The other five have numbers but no names. No. V is the nearest of all, is of mag. 13, diameter 100 miles, distance 112,500 miles, and revolves in the brief time of 11 hours, 57 minutes. The remaining satellites are very small and very distant, and for their details we must refer the reader to the *Observer's Handbook*, though it may be added that their orbits are highly inclined to Jupiter's equator and that Nos. 8 and 9, like Saturn's Pheobe, revolve backward. All the satellites that shine on Jupiter at any one time do not furnish more than 1/16 of the amount we receive from our full moon.

OCCULATIONS. TRANSITS AND ECLIPSES—These are constantly occurring. About 9,000 eclipses occur annually. Nos. I, II, III, are eclipsed every time they revolve because they are in almost the same plane as Jupiter's equator, but No. IV escapes sometimes because of greater inclination. It was the difference in the times of these eclipses that attracted Roemer's attention, and from it, by careful calculation, he was able to measure the speed of light and the distance of the sun.

LIFE—From the various conditions noted above it will be quite evident to everyone that life as we know it cannot possibly exist on Jupiter or his satellites.

Lambeth, Ontario.

NOTES AND QUERIES

Communications are invited, especially from amateurs. The Editor will try to secure answers to queries.

Before and After

In the daily newspapers of January 22, 1927, was a despatch emanating from Chicago which said:—

Herbert Janvrin Browne of Washington, ocean meteorologist and long-range weather forecaster, in an address before the National League of Commission Merchants, said:

"The crop seasons of 1927 in the Northern and Southern Hemispheres are fraught with grave dangers to the grain harvests of the world."

The year 1816 is known in history as the year without a summer, he said and should there be one great volcanic explosion this year like that of Tomboro, in the Dutch Indies, in 1915, the upper air would again be filled with clouds of volcanic dust to shut off the sun's heat and become the final blow in ensuring a recurrence of 1816.

"Weather predictions, based on changes in solar radiation and their effects on ocean temperatures, indicate a severe year," he said, "and should an event such as the one referred to above occur we may see a summerless year such as was experienced 111 years ago."

The summer is now past and we can compare the predicted "summerless year" with the season we actually experienced. It is generally agreed that in Ontario the summer was one of the pleasantest in many years. The temperature was perhaps rather more equable than usual, though the official meteorological report no doubt will state that the mean temperature differed very little from that of other years. The harvest in Ontario was excellent. In the Canadian west, the great wheat crop was distinctly above the average, and I am told that the United States west was similarly favoured.

The futility of the long-range forecasts was never better illustrated, but I suppose they will continue as before. One 'hit' carries more weight with many people than a dozen failures. During the past summer the capricious behaviour of one or two low-pressure areas as they crossed the continent misled the Canadian forecasters

somewhat, and a number of persons wrote to one of our newspapers accusing our officials of incompetence. The writers did not consider the fact that eighty per cent. of the forecasts are verified and shipping companies and others whose business is dependent on the weather have learned to heed the warnings which are sent out hours before a storm arrives.

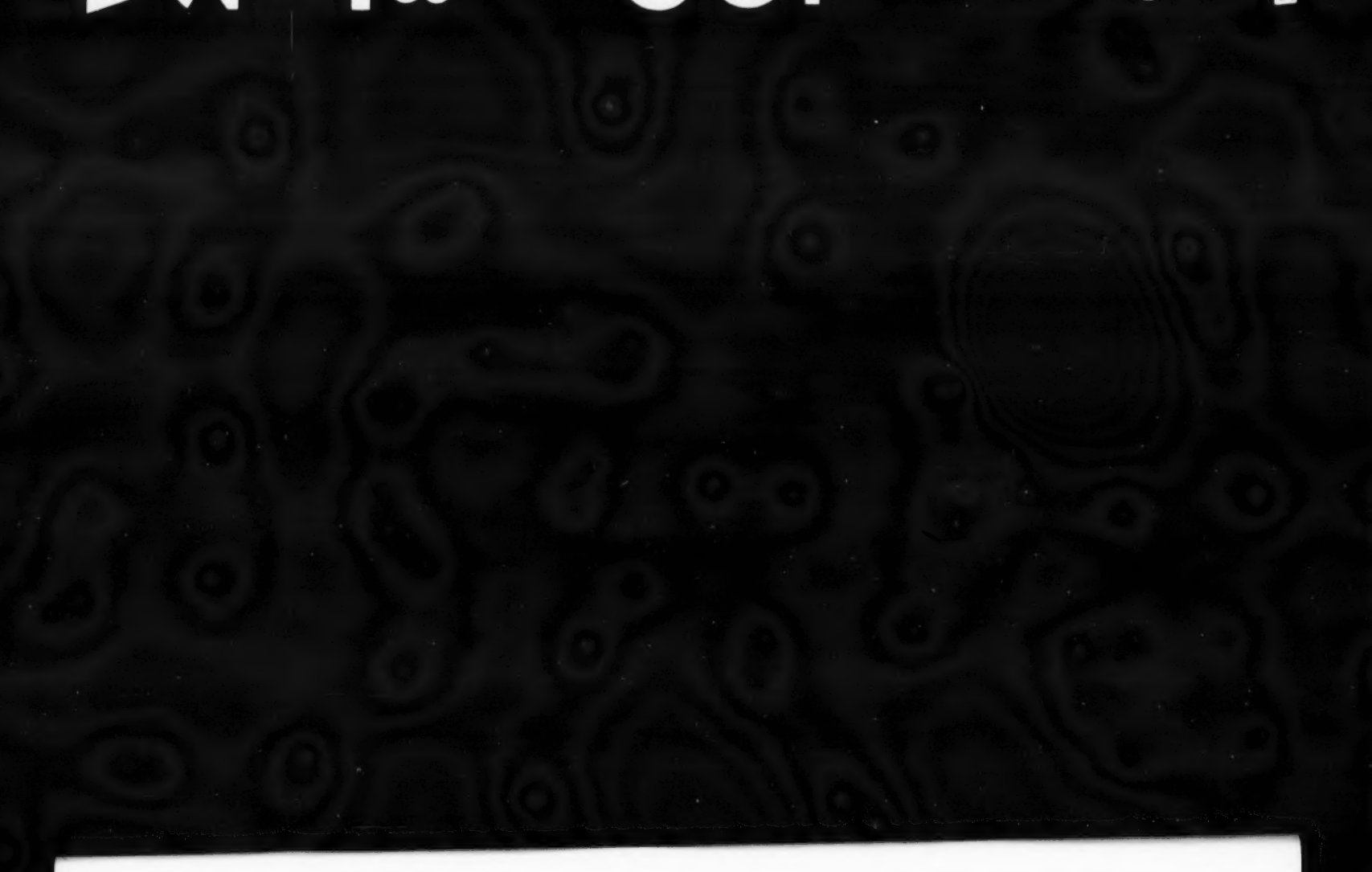
Perhaps I may be allowed to refer to an old prediction and a promise which up to the present has never failed, and which I believe is more trustworthy than the gloomy predictions of long-range weather forecasters:—

"While the earth remaineth, seedtime and harvest, and cold and heat, and summer and winter, and day and night, shall not cease."

The Toronto Centre

Heretofore the ordinary meetings of the Society at Toronto have been conducted by a committee of the General Council, the President or a Vice-president usually acting as a chairman. This arrangement was simply a continuation of the custom which prevailed when there were no centres outside of Toronto. At the last meeting of the Council, however, it was resolved to form a separate body to carry on the local ordinary meetings. It was felt that by making a distinction between the general and the local officers all the centres would be organized on similar conditions and the work would be more effectively carried on. The local organization will begin to function this autumn.

C.A.C.



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